POLYTECHNICAL UNIVERSITY OF MADRID

Identification of voting systems for the identification of preferences in public participation. Case Study: application of the Borda Count system for collective decision making at the Salonga National Park in the Democratic Republic of Congo.

FINAL MASTERS THESIS

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Identification of voting systems for the identification of preferences in public participation. Case Study: application of the Borda Count system for collective decision making at the Salonga National Park in the Democratic Republic of Congo.

Abstract:*The aim of this paper is to review the literature on voting systems based on Condorcet and Borda. We compared and classified them. Also we referred to some strengths and weaknesses of voting systems and finally in a case study, we made use of the Borda voting system for collective decision making in the Salonga National Park in the Democratic Republic of Congo.*
Keywords: *Voting systems; Comparison; Classification; strengths and weaknesses of voting systems; Salonga National Park.*

1. Introduction

The identification of preferences within a public participation process seems to have originated in the voting system procedures proposed by Ramón Llull in the 13th century. To this end, a general method or 'Ars generalis' was developed at the end of the 13th century, based on binary combinations of a series of principles or simple basic categories. Said procedures establish a voting system based on binary comparisons of candidates, and therefore the winner is the candidate that wins by majority due to the greatest number of comparisons.
One of the main contributions of Ramón Llull's concepts has been the appearance of the governance of the majority as a new general principle for legally binding collective decision making instead of the traditional requirement of unanimity (Colomer J.M., 2013)[1]
Nevertheless, to ascertain that the two essential requirements for any decision, the probability of consecution of a decision and the correctness of the decision, the following is needed:

1. In the case of decisions on complex matters, to guarantee that the simple propositions they are made of are rigorously developed, and that the possible opinion is well presented and takes into account the proposal of each voter.
2. The voter is required to be informed so as not to make a mistaken decision (Condorcet, M., 1794, Borda, J.C., 1799)[2,3].

18th century Europe is known as the Century of Lights or Enlightenment, a time in which the dominant thinkers began questioning the traditional forms of authority and power, as well as the moral rules supporting those traditions. One of the most important and lasting contributions of that time was the idea that the existence of a government has to be based on the protection and support of the immutable, natural rights of the citizens. Among these rights is the right to self-government, autonomy of thought and equality. The inherent virtue of these ideas forced many European countries to renounce to their aristocratic systems. The natural rights expounded in that time are immutable, which means they are not rights granted by the government but inherent to mankind. Although modern democratic governments make great efforts to achieve the ideals of that time, they can serve citizens better making use of the technological progress of the information era to increase citizen participation.
Modern nations have the obligation of improving their systems so as to better guarantee respect of the rights of mankind. Engraved in his Memorial, this was Thomas Jefferson's (1743-1826) declaration together with another thinker of the time: "[…]

Institutions must go hand in hand with the progress of the human mind. As it becomes more developed, more enlightened, […], institutions must advance also to keep pace with the times".
To continue making progress in this direction, the principle of citizen representation, articulated by Thomas Paine (Englishman: 1737-1809) and the principle of competitive actors for the common good as articulated by Adam Smith (Scotland: 1723-1790) are hereby regarded from the perspective of collective decision-making systems. On the other hand, these principles can be understood as being part of the requirements for optimal decision making, framed in the mathematical statements of the Marquee of Condorcet (Frechman: 1743-1794). (Rodriguez, M.A., 2009)[4].
With regards to Collective Decision-Making Systems (CDMS), currently research is being carried out in these areas:
Voting systems, prediction markets, information dissemination and recommendation systems.

- Voting systems

  What does "real" democracy look like? In the CDMS, new governance models are studied. With the right tools, it could be possible to one day achieve a more adaptivelarge-scale decision making process for society.

- Prediction markets

  What does the future hold in store? If all the fragments of information contained within a collective entity are aggregated correctly, may the future be known? What does this say about the nature of determinism? And yet more importantly, can money be made with CDMS?

- Information dissemination

  How are ideas disseminated across a population? CDMS develop tools to ease dissemination of information throughout great collectives. Here, the actions of individuals integrated in a social network provide the means for dissemination of the contextualized information.

- Recommendation System

  Can a collectively generated network of heterogenic objects be used as the substratum for the quest for solutions for the problems of an individual? CDMSs explore the role of semantic networks and the future of the resolution of collective problems in a variety of environments[5].

To conclude this introduction, it is worth highlighting the importance the identification of the preferences of individuals has in collective decisions in a public participation process. Research on this subject was carried out driven by the interest of knowing the different methodologies that exist to identify the preferences of individuals as well as, on the other hand, establishing comparison and classification of the different methodologies to this purpose. Likewise, we are interested conducting research on the subject of identifying preferences for collective decisions.
In the context of identification of methodologies for the identification of preferences, the present research was carried out with a series of scientific publications (with a

gathering of bibliographical information) where the main ideas stated by each author on the subject have been summarized.

In the first section, we shall take a look at the voting systems used for collective decision making. A compilation of different preference identification methodologies for the voting systems shall be defined and said systems shall thus be classified.

In the second section, we shall perform a comparison of the different voting systems. Voting systems based on the Condorcet procedure shall be compared with positional voting systems or Borda based systems.

In the third section, reference shall be made to some strengths and weaknesses of the voting systems.

In the fourth section, we shall provide a potential contribution of this work. This is a study case in which the Borda voting system shall be applied to the Salonga National Park in the Democratic Republic of Congo for collective decision making to select a management model. This shall be followed by a section of conclusions.

2. Work Methodology

We shall look for information regarding the collective decision making systems in scientific articles, books and internet upon which to base the investigation. The documental sources of the original articles (primary sources) have been taken into account, as well as the secondary sources. The review of the study of articles has enabled us to conceptually define the terms of our search and has likewise enabled us to have the elements for the conclusion.

3. Voting Systems

In this section, we have compiled different methodologies to identify preferences for the voting systems. The aim is to provide the key or main ideas of each enumerated methodology.

The precursory work of Ramon Llull

Llull proposed a system of exhaustive binary comparisons that is more efficient to know the winner in the Condorcet procedure. Llull wrote at least three works on voting and elections:

- *Artifitium electionis personarum* (c.1274-1283) (the method for electing people) (AEP)
- *En cual manera Natana fo electa a abadessa* (c. 1283) (How was Natana elected as abbess) (B24)
- *De arte electionis* (In the method for elections) (1299) (DAE).

In AEP, Llull presents his initial proposal for voting in academic form and introduces a graphic representation of the binary comparisons of the candidates. B24 is chapter 24 of Blanquerna, originally written in Catalan and regarded as one of the first novels written in a Romance language, where the election of the abbess of a convent is used as an occasion for dissemination.

Llull's proposal was the first serious attempt at creating a system capable of putting in practice the majority principle in real elections. Therefore, his work is considered as being foundational and precursory.
According to the Llull voting system, the election shall be held through the holding of several rounds of majority voting among all possible candidate pairs. For n candidates, this requires *n (n-1)/2* comparisons. The winner is the majority candidate in the greatest number of binary comparisons (Colomber JM, 2013).
Later on, the most two most popular families of voting norms are the Condorcet methods, which elect the winner when there is one, and the Borda scoring methods, which assign points to each candidate according to a ordering of the candidates (Moulin, 88)[6].

3.1 Definition of voting systems

Condorcet Methodology

The **Condorcet** method is a voting system that serves to elect a person among a group of candidates. Voters order candidates from greater to lesser level of preference.

- Order the candidates by order of preference. Draws are allowed, that is, to give the same preference to two candidates if no special interest is invested for any of them.
- Compare each candidate in the voting slip with each one of the rest. The one with the greatest preference scores a point.
- Add up the victories of each candidate. The candidate that has beaten each candidate more times than the times they have lost is the preferred one and wins the election.
- In case of a draw, use one of the methods described further down (Young, H.P., 1988)[7].

Borda Methodology

Each voter states their preferences as per the ranking of candidates*p* from top to bottom. A candidate does not receive any points for being in the last place, a point for being in the second to last position, and so on up to *p-1*pointsfor being in first place. The candidate with the highest total scoring is the Borda winner.

In other words, voters score all candidates from highest to lowest according to their preferences and the candidates with the highest overall score wins.
Let's consider a finite set of alternatives (or candidates) $X = \{x_1, x_2, x_3\ldots\ldots,x_n\}$, with $n\geq 3$. We could say that P is a relationship of preference over X if P is an asymmetric binary relationship, that is: if $x_i\ P\ x_p$,, then $x_j\ P\ x_i$, cannot happen. The relationship of indifference I associated to a P preference relationship picks up the absence of preference: $x_i\ I\ x_j$, means that neither $x_i\ P\ x_j$, nor $x_j\ P\ x_i$. The weak relationship, finally, $P\ U\ I$ includes both the preference as well as the indifference: $x_i\ (P\ U\ I)\ x_j$ means that $x_i\ P\ x_j$, or $x_i\ I\ x_j$. Given P^k as the agent relationship preference k (k = 1, 2,……., m) regarding the set of n alternatives for X. Such a relationship of preference can be associated to the following matrix:

$$\begin{pmatrix} r_{11}^k & r_{12}^k & \dots & r_{1n}^k \\ r_{21}^k & r_{22}^k & \dots & r_{2n}^k \\ \dots & \dots & \dots & \dots \\ r_{n1}^k & r_{n2}^k & \dots & r_{nn}^k \end{pmatrix}$$

Where: $r^k_{ij}=1$ *if* $x_i \, P \, x_j$, and $r^k_{ij}=0$, in the other case.
The Borda Aproach: individual Borda scores assigned by agent *k* regarding alternative x_i, that are given by:
$r_k\,(x_i)=\Sigma^n_{\Omega}\, r^k_{ij}=\Sigma^n_{j=1}\, r^k_{ij}$ with Ω equivalent to $(j=1, x_i P^k x_j)$.
This individual counter reflects Borda's idea that to each x_i alternative, the agent *k* assigns as scoring the number of alternatives that for him are the worst. Another alternative for this value is the summing up of the coefficients of the i-esimal row of the individual preferences matrix. It is worth stating that the possible range of values is between the set {*0, 1, 2,…… n-1*}. That some superior values are reached or not depends on the absence or presence of indifference between the different alternatives, respectively. With these individual scores, on each individual alternative, a collective can be defined as follows:
$r(x_i)=\Sigma^m_{k=1}\, r_k\,(x_i)$, using the Borda method, the alternative(s) with the highest score are/is the winner(s) (Panero M.M, 2006)[8].
Below we have included an example of the two most popular voting systems, the **Condorcet and the Borda** families. Daugherty (2004)[9] illustrates how these two methods are different. Let us say that we ask voters to classify three candidates *A*, *B* and *C*. To represent *A* defeats *B*, we will write *A>B*. Let us suppose that 18 voters choose according to the following classifications:

Table 1: Preference Classification (Source: Duagherty, 2004)

Votes	Classification
2	*A>B>C*
5	*A>C>B*
2	*B>A>C*
4	*B>C>A*
1	*C>A>B*
4	*C>B>A*

Therefore, we could compile these data in a profile, *p*, representing the number of people voting for each candidate classification. The profile for this result, if we order the classification alphabetically, is *p = (2, 5, 2, 4, 1, 4)*. If we use the **Borda** methodology, the result of these votes would give 10.5; 9 and 8.5 points to *A, B*, and *C*, respectively, giving a general classification of *A>B>C*. However, if we choose to calculate the classification (ranking) by pairs (**Condorcet methodology)**, we find the following count:

Table 2: Candidate Scoring (Source: Daugherty, 2004)

Score	Pair
8	*A>B*
8	*A>C*
8	*B>C*
10	*B>A*
10	*C>A*
10	*C>B*

This gives a transitive classification of *C>B>A*. We hereby state that these two calculation methods are totally contradictory between themselves in this case. This is what is known as a paradox, as the different results were calculated using two apparently fair calculation methodologies.

The Copeland Method

This methodology compares candidate *a* with any other candidate *x*. They shall score +1 if the majority prefers *a* over *x*, -1 if the majority prefers *x* over *a*, and 0 if the result is a draw. Summarizing the results of *a* over all the different *x* candidates, we obtain the score for *a*. A candidate with the highest score, called the Copeland winner, is chosen (Faliszewski, P et al, 2008)[10].

Paired Comparison Methodologies

Given *A* as a finite set of "alternatives" (for example, candidates) and *V* a finite set of individuals (for example, voters), individuals can express their opinions collectively by establishing a classified list from "most preferred" to "least preferred" through some voting mechanism choosing some or all the alternatives in *A*.

Paired comparison methods are schemas designed to establish a classification (or partial classification) of the elements of a set, A, based on the comparisons amongst the elements in some (or all) the pairs of elements in *A*. One of the most popular of these methods is owed to **Zermelo** (Anderson, L.B, 2009)[11].

Coombs Methodology

The Coombs method is a voting system created by Clyde Coombs, used in elections to choose a single winner. Each voter classifies candidates by preference order (Grofman, B. and Feld, S.L. 2004)[12].

Slater Methodology

Given a set of candidates, for each pair of candidates, *a*, *b*, such that *a* is in a higher ranking than *b*, but *b* defeats *a* in an election by pair, this seems to be a contradiction and an ordering is a Slater ranking if it minimizes this type of inconsistencies (Conitzer, V., 2006)[13].

Simpson Methodology

This method consists of a candidate *a*, and for all other candidates *x*, it calculates the number *N (a ,x)* of voters that prefer *a* to *x*. The Simpson score for *a* is the minimum of *N (a, x)* of voters that prefer *a* over *x*. The Simpson score for *a* is the minimum of *N* (*a, x*) over the other *x* candidates. The candidate with the highest score, called the Simpson winner, is chosen (Levin, j. and Nalebuff, B., 1995)[14].

Kemeny Methodology

The Kemeny voting system stands out because it is the only voting system that is neutral, coherent, and applies the Condorcet theorem. A voting scheme is defined in which the election of winning candidates is based on the classification according to the electoral preference. In the case of two candidates, it is not trivial to say what the correct manner of assessing the classification of voters is. As an example of the difficulties produced, we can observe the Condorcet paradox that goes back to 1785: let us suppose that there are 3*n* voters with a preferential classification of *a*>*b*>*c*, *b*>*c*>*a* and c>a>b, for *n* electors. If we assess the classification by the majority rule, then we have a cyclical aggregate order of preference: *a* defeats *b*, *b* defeats *c*, *c* defeats *a*.

Now, the Kemeny system is a preferential voting system. Each voter issues their vote via a classification of all the candidates by order of preference. Draws are allowed. For example, a voter can classify candidates *a, b, c, d* and *e* by order of preference *a*>*b* = *c*>*d*>*e*. The candidate *a* is the favorite, and *e* is the candidate with less favoritism in the classification. Candidates *b* and *c* are considered of equal convenience, that is to say, they are linked. A classification of preferences without draw is called a strict order of preference. Each voter identifies with their preference order, and the set of voters is regarded as a set of multiple preference classifications.
Kemeny defined the result of an election as a collection of lists of preferences that is "closer" to the list of preferences of voters. Such an order of preference is called a Kemeny Consensus. A candidate is the winner of the elections if they are a preferred candidate in a Kemeny Consensus.
There are different manners of defining proximity. For Kemeny elections, the objective is to reduce the Kemeny punctuation to the minimum: the sum of the distances to the lists of preferences of the voters. For each pair *P, Q* of classifications of preference, the distance is defined as:

$dist\ (P,Q) = \Sigma_{\{c,\ d\}} d_{P,Q}(c,d)$, where the sum of all the non-ordered pairs are taken $_{\{c,\ d\}}$ for the candidates and,
$d_{P,Q}(c,d) = 0$ if *P* and *Q* agree in *c* and *d*.
$d_{P,Q}(c,d) = 1$ if *P* or *Q* have a preference between *c* and *d* and the other does not,
$d_{P,Q}(c,d) = 2$ if *P* and *Q* agree strictly between *c* and *d*.
Given a set of candidates *C*, and a multiple set of preference classifications *V* over *C*, the following 3 functions are defined for the Kemeny scoring:

- For each *P* over *C* order of preference:

$Kemeny\_Score\ (C,V,P) = \Sigma_{Q \in V}\ dist\ (P, Q)$.

For candidate $c \in C$,

Kemeny_Score: (C,V,c) = min {Kemeny_Score (C,V,P) |P is an order of preference in *C*, and *c* is a candidate preferred in *P*.

- *Kemeny_Score (C,V,P) |P* is a preference order in *C* (Hemaspaandra E. et al, 2005)[15].

Dodgson Methodology

In the Dodgson Methodology, each voter presents an ordered list of all the candidates, as a function of their own preference (from best to worst).
The election is won by the candidate (s) that is (n) "closer" to being the winner of Condorcet: that each candidate is assigned a score that is the number if exchange of adjacent preferences in the order of preferences of voters to make the candidate be the Condorcet winner regarding the resulting preference orders (Hemaspaandra, E, et al. 1997)[16].

Young Methodology

The principle of the Young voting rule is similar to Dodgson's but in this case the scoring of a candidate *x* is the lower number of voters whose elimination makes *x* the Condorcet winner (Rothe, J. et al., 2003)[17].

Banks Methodology

A Banks winner for the collection of *P* profiles is the higher vertex of any sub-trophy for graph M_p (Banks, J.S. 1985)[18].

Methodology of the Approval Vote (*approval voting)*

The approval voting is a voting method in which voters may vote for all candidates as they wish in an election. They are normally used in elections with a single winner, it may however extender to elections with multiple winners. The approval vote is a primitive form of valuation vote, in which a somewhat more complex valuation is allowed for candidates (for example, scoring them). However, in the approval vote, only "acceptance" or "non-acceptance" is allowed (Brahms J.S. and Fishburn, P.C., 1978)[19].

Negative Vote Methodology (*negative voting)*

This is a voting system proposed by Boehm. Under the negative vote, each elector is allowed to vote for a candidate. This vote can be favorable or against the candidate. A vote in favor adds to the score of the candidate and a negative vote subtracts a point from the candidate scoring. The result of the negative voting in the voting system is the subset of candidates with greatest total net voting (the sum of points in favor and against), which can be negative (Brahms, J.S. and Fishburn, P.C., 1978)[19].

Uninominal majority Scrutiny Methodology (plural voting system)

This is a voting system in which the candidate can only vote for a single candidate and the winner of the election is the candidate receiving the greatest number of votes. This concept is also known as the relative majority or plurality concept[20].

Second electoral round Methodology (Ballotage)

The second electoral round (**Ballotage** or **balotaje** in Spanish) is the term used to designate the second round of voting in elections for executive or legislative positions. The word Balotaje comes from the verb Balloter, which means voting with ballotets, balls (ballots). Balotaje means the election with a second round. In the ample sense, it means that for accessing the corresponding public office, half of the issued votes are needed (Messner M., and Polborn, M. 2005)[21].

Schultze Methodology

The Schulze method is a voting system developed in 1997 by Markus Schulze that selects a winner according to the voters' preference. This method can also be used to create a list of winners.

The Schultze Methodology consists of:

1. Finding out the Schwartz set (the lowest set of candidates that is not won by anyone outside the set). If there is only one candidate in the set, this is the Condorcet winner. If there are several members but no defeats among them, there is a normal draw amongst them.
2. In any other case, eliminate the softest defeat in the Schwartz set (that is, won by the smallest margin). Recalculate the new Schwartz set and repeat the process (Schulze, M., 2003)[22].

"Unrestricted pointing-voting scheme" Methodology.

This scoring rule is flexible and assigns voters an equal number of scoring and does not impose any limitation on the assignment of the initial amount of scores amongst candidates (Nitzan, S. 1985)[23].

Cumulative Voting Methodology

This is a methodology in which n voters assign k points to the candidates and that is used in a election quota ($qo= (nk+1)/ (k+1)$.Any candidate obtaining at least q votes is chosen (Bolger, E.M., 1985)[24].

Transferable single Vote Methodology (Single Transferable Vote)

It is a system in which a vote is initially assigned to the voter's favorite candidate, and if the candidate has already been elected or eliminated, all the surplus votes are transferred according to the voter's preferences. The candidate that has obtained the quota $q = [n /(k+1]+1$, where n represents the issued votes and k the positions to fill, is the winner (Levin, J. and Nalebuff, B., 1995).[14]

Additional Members System Methodology ("adjusted district voting")

This is a system in which people vote separately for the candidate and the party of their preference. Additional chairs are assigned to the party if the number of circumscriptions winning does not reflect their total participation in the total of the votes (Brams, S.J. and Fishburn, P.C., 1991)[25].

"Reducing to the minimum the representation imbalance" ("Minimizing the representational imbalance) Methodology

This is a system proposed by Monroe (1995)[26]. The idea is to assign approximately the same number of electors to each candidate to reduce the imbalance of representation in an election.

Black Methodology

This is a voting procedure that elects the Condorcet winner (if there were any); if this were not the case, the Borda winner is appointed (Black, D. 1948)[27].

Nanson and Baldwin Methodology

It is a voting procedure that iterates the alternatives to reach the mean Borda scoring. At the end of the process of iteration, one alternative is left or a group of alternatives with a draw, and a winner is selected if Condorcet exists (Narodystka, N., 2011)[28].

3.2 Voting Systems Classification

We could establish a general classification of the different voting systems in the following way:
The two voting super classes are the Condorcet and the Borda method.

A. The "Condorcet Winner" Class

The first two super classes for voting that follow are susceptible of producing a Condorcet winner: the Copeland Fishburn method, the Nanson Method, the Condorcet Method, the Black method, the Kemeny Method, the Dodgson Method, the Young Method, the Schwartz Method, the Miller Method, the Banks Method and the Slater method.

B. The "positional scoring procedures" class

These are systems that serve to produce a winner granting scorings to different candidates. Within this class, are the Borda Methodology, the plural voting system and the "unrestricted point-voting scheme"

C. The "Hybrid Voting System"

We could group some voting systems in a class called "hybrid voting system". Panero (2006)[8] states that this reconciles the Codorcet principle (non-positional focus) with the

Borda rule (positional focus). For example, the Nanson and Baldwin, Black and Kemeny voting system are hybrid systems.

D "Score distribution Procedures" Class

All the voting procedures previously described use both an unclassified voting system (for example: Condorcet methodology) or a classified system (Borda methodology). These systems do not allow voters to express their preference *intensities* in a more complete manner. The distribution procedures accommodate the possibility requesting each voter the distribution of a specified number of points among the candidates in any form that they wish. The candidates with the highest points are the winners. The usual term for this procedure is the cumulative vote. The elector has the possibility of giving different votes to a single candidate and this serves to foster the minority representation.

E. "Proportional Representation" Class

The proportional representation system is an electoral system in which the percentage of votes received by the political parties determines the number of seats that are assigned in legislative assemblies or parliaments.
The different systems of proportional representation are:

- Single transferable vote. This is a voting system based on proportional representation
- Additional members vote (*Adjusted District Voting)*
- The methodology of reducing to the minimum the representation imbalance (*"Minimizing representational imbalance").*

F. "Unclassified voting Procedures" Class (*non-ranked voting procedures).*

Within the unclassified voting systems we can also find the approval voting, and the negative voting.

Table 3 summarizes the different classes. (Source: own elaboration)

"Condorcet Winner" Class	**"Positional scoring procedures" class**	**"Hybrid voting systems" class**	**"Score distribution procedures" class**	**"Proportional representation" class**	**Non-classified voting procedures**
Copeland method	Borda Methodology	Black Method	Cumulative Vote	Single transferable vote	Approval vote
Fishburn Method	Plural voting system	Nanson and Baldwin method		Additional members voting	Negative vote
Nanson Method	Unrestricted point-voting scheme	Kemeny Method		Representation imbalance reduction to the minimum	
Condorcet Method					
Black Method					
Kemeny Method					
Dodgson Method					
Young Method					
Schwartz Method					
Miller Method					
Banks Method					
Slater Method					

4. Comparison among the voting systems

This section, after having identified some voting systems, helps us focus on the comparison among different identified voting methodologies. The two most popular families of voting systems are the Condorcet method, that selects Condorcet winners when there are none, and the Borda scoring methods, that assign points to each candidate according to their classification as per the opinion of voters (Moulin, H. 1988).
As main properties (or criteria) for the voting systems, supposedly the voting systems must have 3 of the following basic properties (Martin, W.E. et al, 1996)[29]:

1. A Pareto Optimal (Pareto Condition). If candidate *a* is preferred by unanimity over candidate *b*, then candidate *b* cannot be elected.

2. Anonymity. The names of voters do not matter: if two voters exchange their votes, the result of the election shall remain unchanged.
3. Neutrality: the names of the candidates have no relevance: if candidates *a* and*b* exchange in the order of all voters, then, in the results of the elections, *a* must be substituted by *b* and vice versa. Nevertheless, the following must be taken into account:
    - Monotony: If *a* wins the elections with a preference profile, then he or she shall continue being the winner in any other profile obtained from the original one via an improvement of the classification of *a* in the opinion of the voters, without affecting the relative classifications of the other candidates.
    - Reinforcement: Let us suppose that two disconnected groups of voters face the same list of candidates and both select *a*. Then, if two groups vote together, they should still vote for a.
    - Participation: Let us suppose that a group of voters select *a*. If this group increases by and additional voter, then the new electoral mass must select *a* or a candidate that the new voter prefers strictly to *a*.

      There are two other questions related with voting that must be taken into account, that is, the possibility that the voters may benefit from distorting their preferences (instead of voting for their favorite candidate *a*, a voter supports the second option *b* preferred by *c*, acknowledging that a has no possibility of winning) and that the result of the elections may be manipulated by voter coalitions.
    - "*Strategy-proofness"* A voting rule that is a "test strategy" if every individual voter maximizes their utility reporting their opinion.

    - Nucleus stability: A voting rule is the stable nucleus if there is no winning coalition that can find a voting strategy that could increase the utility of each member of the coalition. A winning coalition is the set of voters that can force an election of a candidate regardless of what the rest of the voting population votes.
    - Homogeneity: If the electorate is divided into *N* voters, and each one of them has the same preferences of the original, it would be difficult to imagine why the set of the election should change (Fishburn,P.C., 1977)[30].
    - The Smith Condorcet Principle. In voting systems, the Smith set is the smallest non-void set of candidates so that each member defeats any other member out of the set in an election by pairs of candidates.
    - Condorcet transitivity: If you consider *y* as a viable candidate for the single final election and if x has the simple majority over y, then x also must be considered as a viable candidate for the final election.
    - Consistency. If $p(p_{1\ldots}p_{r)}$ and $q(q_1\ldots..q_s)$ are preference profiles, then (p,q) denotes the profile $(p_{1\ldots\ldots}p_r,q_1\ldots\ldots q_s)$. Therefore (p,q) may be seen as a profile obtained for the set of two unconnected voting bodies.
    - Discriminability: The capacity of a voting system of producing only one winner.

4.1. Condorcet based Voting System

A series of voting procedures has been proposed whose goal is to elect a strict **Condorcet** candidate when there is one. A Condorcet voting procedure is said to be one when there is a strict Condorcet Candidate. A dozen Condorcet methodologies, procedures or voting procedures have been defined (Brams, S.J., and Fishburn, P.C., 1977, 2002)[31].

Table 4: Comparison of some voting systems using the Condorcet Procedure (Source: own elaboration)

	A	B	C	D	E	F	G	H	I	J	K	L
Copeland Method	Yes	Yes	Yes	Yes	Yes	Low	No	No	No	No	No	Yes
Fishburn method	Yes	Yes	Yes	Yes	Yes	Low	No	No	Yes	Yes	Yes	Yes
Nanson Method	Yes	Yes	Yes	No	Yes	High	No	No	Yes	No	No	Yes
Condorcet Method	Yes	Yes	Yes	Yes	No	High	No	No	Yes	Yes	Yes	Yes
Black Method	Yes	Yes	Yes	Yes	No	High	No	No	Yes	Yes	Yes	Yes
Kemeny Method	Yes	Yes	Yes	Yes	Yes	High	No	No	Yes	No	No	Yes
Dodgson Method	Yes	Yes	Yes	No	No	High	No	No	Yes	Yes	Yes	Yes
Young Method	Yes	Yes	Yes	Yes	No	High	No	No	Yes	Yes	Yes	Yes
Schwartz Method	Yes	Yes	No	Yes	Yes	Low	Yes	Yes	Yes	No	No	Yes

A: anonymous; B: Neutrality; C: Pareto Condition; D: Monotony; E: "Condorcet principle" of Smith; F: discriminability; G: consistency, H: Condorcet Transitivity; I: Inclusive Condorcet Principle; J: Condorcet Exclusion Principle; K: Strict Condorcet Principle; L: Homogeneity.
For further details on the Miller, Slater and Banks procedures (refer to Hudry, O, 2009, and Miller, 1980)[32,33].

4.2. Borda based voting Systems

Score positional procedures include the Borda Method and those in which differences among scores given to candidates in successive positions in the ballot of voters are not the same.
Within the voting systems using the scoring system we find the Borda methodology, the plural voting system, and the "unrestricted point-voting scheme". The "unrestricted point-voting" methodology and the Borda Methodology have been described in section 1. The plural voting system is characterized by assigning 3 points to a candidate occupying the first place, 1 point to the candidate in second place and 0 points to the last place. Therefore, the points granted to candidates would be $s = (3,1,0….0)$. In the table, we can observe some properties of positional voting systems.

Table 5: Comparison between positional voting systems (Source: own elaboration)

	Anonymity	Neutrality	Monotony	Consistency	Manipulation
Borda Methodology	yes	yes	yes	yes	no
Plural voting system	yes	yes	yes	yes	yes
"unrestricted point-voting scheme"	yes	yes	yes	yes	yes

All positional voting systems are susceptible of manipulation except the Borda voting system, which is less susceptible to manipulation (Saari, D.G. 1990)[34].

5. Some strengths and weaknesses of the voting systems

Some voting procedures may be controlled by the authorities in charge of the election process to achieve strategic results. For example, it could be possible to influence the result of an election through the specification of the sequence in which the alternatives are to be taken into account, or through the specification of the composition of the sub-committees that nominate candidates.

Bartholdi, J.J. et al (1992)[35] have studied how influence could or could not be exerted on the results of an election. This would represent the weaknesses or strengths of the voting system. They centered on the *plural* voting system and the *Condorcet* voting system.

The *plural* voting system selects the winner as the candidate with the most votes over the rest of the candidates. By the *Condorcet* system, we refer to any procedure that always selects the candidate that would defeat any other in even condition elections.

It is said that a voting system is *immune* to control if it is not possible to change a "non-winner" candidate to "single winner" via manipulation of the voting procedure. If not, the system is *susceptible* to control. For such a system therefore, we can say that it is *vulnerable.* If not, then the system is *resistant* to control. The types of control can imply addition, elimination or partition of the set of candidates or of the total of voters.

Voter Participation

Let C be the universe of candidates. Let us consider the possibility of an election that is in two stages, based on the participation of the candidates in the C_1 and C_2 subsets. $C_1 \, U \, C_2 = C$ and $C_1 \cap C_{2 = 0.}$ In the first place, all the electoral force votes for the candidates from C_1; then, the winner of this election must face the candidates from $C_{2.}$ Could this happen in elections by partition of C_1 and C_2?

In general, the plural voting system resists control of candidates, while the Condorcet system resists control of voters.

Table 6: Strengths and Weaknesses of the plural voting system and of the Condorcet voting system (Source: Bartholdi, J.J. et al, 1992)

	Candidate addition	Voter Addition	Candidate Elimination	Voter Elimination	Candidate Partition	Voter Partition
Plural Voting System	resistant	vulnerable	resistant	vulnerable	resistant	vulnerable
Condorcet Voting System	immune	resistant	vulnerable	resistant	vulnerable	resistant

6. Study Case: application of the Borda methodology for collective decision making at the Salonga National Park in the D.R. of Congo

The objective of this second part is to review a group decision making process using the social election theory, specifically the Borda voting system. The elements of a social election problem are the voters, the alternatives, the preferences and the aggregation.
As part of the approach on soil use management, the Forestry Service (NFMA: National Forest Management Act) has developed a system to support the decision in which participative decision making is an important component. To help reduce the possibility of conflicts to the minimum in the forestry planning process as there are so many competing uses for scarce resources, a model defining the voters that can take part and the election of alternative scenarios for development and conservation was developed. (Martin WE, 1996)[36].
According with the Borda methodology defined in section 1, we shall consider a set of alternatives *A* that would represent the different Salonga National Park management models. Voters or participants, $P\ (P_{1.....}P_m)$, where $m=7$, would represent the different stakeholders involved in the management of Salonga National Park and said voters would score all the alternatives from higher to lower in accordance with their preferences and the alternative with the greatest overall score would prevail.
Following, the study case focuses on Salonga National Park. We intend to apply the Borda voting system to select an alternative for management of the Park. The following system briefly describes the Park and the problems inherent to the aforementioned. The Democratic Republic of Congo has over 145 millions of hectares as forest space, that is, 26% of the total rain forests in the world and over 52% of the forestry layer in Africa. It has a surface of 2,329,374 square kilometers, out of which over 60% is comprised of a forest cover. The country has 5 National Parks out of which 4 have been declared Endangered World Heritage Sites by UNESCO (early 1996).
The Salonga National Park (1°00'-3°20'S, 20°-22°30'E) covers around 36,560 km^2, located in an isolated area with the Congo River basin. It is the second greatest reserve of tropical rainforests in the world. The Salonga National Park is the habitat for many endemic species that in great numbers are in danger of extinction. The Park was declared National Park on November 30, 1970 by virtue of ordinance 70-318, in which was defined as "une reserve naturelle integrale" (integral natural reserve).
This is the greatest dense rain forest area protected in the African Continent. Very isolated and only accessible via water transport, this park contains the important evolution of species and communities in the woodland area that is relatively intact. Also playing a key role in the regulation of the climate and the absorption of carbon emissions, it constitutes a habitat of a number of endangered species, such as the pygmy

chimpanzee (Bonobo), the rainforest elephant and the Congo Peacock. The Park represents one of the rare existing biotopes that are intact in Central Africa.

Besides, it also has ample swamp areas and gallery forests that are practically inaccessible, that have never been explored and that still may be considered as virgin lands. Vegetal and animal life in the park constitutes an example of the biological evolution and the adaptation of forms of life in an environment of complex equatorial rain forests. The great size of the Park guarantees the possibility of an ongoing evolution of species and biotic communities within a relatively intact rainforest.

In 1984, it became a part of the UNESCO World Heritage Site Catalogue. Due to a civil war in the eastern side of the country, it was also added, in 1999, to the list of Endangered World Heritage Sites, due to the retreat of populations such as white Rhinoceroses.
The fact that the park is divided into two distinct sectors gives a great importance to the Monkoto Corridor in the biological processes of the two areas of the park. This zone, due to the anthropic pressure it has been subjected to during many years, as it is the most densely populated area near the park; it suffers the greatest degradation within this habitat. Even so, it works as a biological corridor of the two areas, with a fundamental role in the connectivity of the park.

The National Park suffers great problems, out of which the following stand out:

- Illegal hunting and commercial traffic of meat of wild animals;
- The absence of a legal protective framework;
- Conflicts between local populations, that produce fires, deforestation for crop growing, wood extraction for heating, honey harvesting and construction of boats, disputes over the park limits in certain areas and excavations in search of mineral resources (diamonds, etc).
- Forestry exploitation in the southern part
- Water pollution with toxic products used for illegal fishing.

In 2006, a resolution of conflicts in the park was worked out, due to the growing hostility among local communities and the national authority in charge of managing Salonga National Park[37, 38]. In the city of Monkoto, there was a meeting of high authorities, in which the different parts managed to decrease tensions that had been created. The meeting also marked the first time that a provincial governor went to Monkoto in over 30 years.

Given the multiple problems that the park is being subjected to, and its great value, both nationally and internationally, the use of the theory of Social Election via a **Borda** voting system would try to identify the options or alternatives that are viable for collective decision making for voters so as to draft a management model that eliminates or mitigates all the damage that is endangering its preservation. Despite the existence of a Park Coordination Committee (CoCoSi) and a state regulation currently in force (Code Forestier from 2002), which ensures the conservation of these habitats, their capacity of guaranteeing the future of the park is limited.

In this case, the voters would be:
P_1: the forestry industry (private owned): the société de Développement Forestier (SODEFOR), the Société Forestière et des Matières Ligneuses Africaines

(SOFORMA), the Société Industrielle et Forestière du Congo (SIFORCO), the Compagnie Forestière of Transformation (CFT), the Forestière et Industrie of Transformation du Bois (ITB).
$P_{2:}$ environmental organizations such as World Wide Fund for Nature (WWF), Wildlife Conservation Society (WCS), Zoological Society of Milwaukee (ZSM), FAO, UNESCO, and the United Nations Foundation.
P_3: forest guards from the Salonga National Park.
P_4: mining companies (excavation and prospection of diamonds).
P_5: local communities such as the Kitawalistes, Yaemila, Batua, and the tribe leaders (an estimated 5,000 inhabitants around the park).
P_6: The local governmental entities such as the provincial government of Equateur, the Park Management Committee.
P_7: the national government of the D.R. of Congo represented by such institutions as Institut Congolais of the Conservation of Nature (ICCN), Institut National of Recherche Agraire (INRA).
And the alternatives for participants to choose from would be:
A_1: To leave the park without a management plan (that is, fewer restrictions)
A_2: A plan to raise awareness for the resolution of conflicts of the local populations and the recovery of the forest.
$A_{3:}$ The design of new economic activities for the local community, compatible with conservation.
A_4: The regulation and control of destructive activities (fishing, hunting and armed groups) in the park.
A_5: The regulation and control of mining exploitation activities affecting the forestry areas of the park.
A_6: The development of a system of environmental indicators.
A_7: The design of a specific norm in the park (use and management plan, with more restrictions).
The profile of preference is defined in table 7. The participant must score from 1 to 7 each alternative without being able to repeat the score.

Table 7: Preference Profile representing the scores of participants (Own elaboration)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
P_1	7	6	5	4	3	2	1
P_2	1	2	3	4	5	6	7
P_3	1	3	2	6	4	7	5
P_4	2	6	7	3	1	5	4
P_5	6	7	5	2	4	3	1
P_6	1	5	4	7	2	3	6
P_7	1	7	6	3	5	2	4

Although the scores are a simulation, a guideline of the behavior and the preferences expressed in previous occasions by participants has been followed. That is, historical data has been used, as well as NGOs, civil society, and environmental organizations. Applying the **Borda** rule, we obtain the following table:

Table 8: Application of the Borda rule to the preference profile table. (Own elaboration)

	A1	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*
P1	6	5	4	3	2	1	0
P2	0	1	2	3	4	5	6
P3	0	2	1	5	3	6	4
P4	1	5	6	2	0	4	3
P5	5	6	4	1	3	2	0
P6	0	4	3	6	1	2	5
P7	0	6	5	2	4	1	3

As may be seen in table 8, applying the Borda rule, the least preferred alternative receives the score 0 and so on up to the most preferred alternative 6 = (*m- 1).*

Therefore, **Borda** scores for each alternative would be:

A_1=6+0+0+1+5+0+0=12
A_2=5+1+2+5+6+4+6=29
A_3=4+2+1+6+4+3+5=25
A_4=3+3+5+2+1+6+2=22
A_5=2+4+3+0+3+1+4=17
A_6=1+5+6+4+2+2+1=21
A_7=0+6+4+3+0+5+3=21

The alternatives were enumerated from the alternative with fewer restrictions, A_1, to the alternative with most restrictions, A_7. It must be said that the wood exploitation industries would choose a preferences profile that gives more weight to alternative A_1, that is, a model with fewer restrictions for them, and environmental organizations would prefer a preferences profile that gives more weight to A_7, that is, a more restrictive management model.
The alternative with the highest score would be the **Borda** winner. Therefore, alternative A_2 (with most scoring) would be the most viable as per the **Borda** methodology for the park management.

7. Conclusions

This work has been based, first of all, on the bibliographic revision of some voting systems for collective decision making by identifying them, comparing them and classifying them by establishing a class of "Condorcet winner", a class of "positional scoring procedures", a class of "hybrid voting systems", a class of "Score distribution procedure" a class of "proportional representation" and a class of "non-classified voting procedures" (*non-ranked voting procedures).* Regarding the comparison between the voting systems based on the Condorcet procedure, we have observed that all the systems are compliant with the criteria of anonymity, neutrality and homogeneity. Likewise, all except the Schwartz system satisfy the Pareto Condition and all comply with the monotony criteria except the Nanson and Dodgson voting systems. We must state the fact that all the voting systems comply with the criteria of the "Condorcet Principle" of Smith. In terms of discrimination, the Nanson, Condorcet, Black, Kemeny,

Dodgson and Young systems are discriminatory, while the Copeland, Fishburn and Schwartz are not.
Regarding the comparison of positional voting systems, all systems comply with the anonymity, neutrality and monotony criteria, as well as consistency. But the only system resisting manipulation is Borda.
In relation to the strengths and weaknesses of the Condorcet voting systems, we can highlight that a system is vulnerable in terms of the elimination and partition of candidates, is resistant against addition, elimination and partition of voters. It is a system immune to addition of candidates. While, the plural voting system is vulnerable to addition, elimination and partition of voters, as well as offering resistance against addition, elimination and partition of candidates.
As a relevant point for voting systems, it must be said that there is no single voting system that is perfect, but some systems are clearly superior in comparison with the others in compliance of certain criteria (Brams, S.J. and Fishburn, P.C., 2002).
In second place, in a study case, we have applied the Borda voting system to the Salonga National Park at the D.R. of Congo in order to choose a management model for the Park. This is a simulation that will allow solving some ongoing conflicts in the Salonga National Park since there is no plan for the use and management where the general guidelines for the Park had been defined. This management tool is of utmost relevance to foster an adequate use of the Park, speeding up citizen participation and ensuring sustainable exploitation.

8. Thanks

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To my brother Alain Mukadi in heaven.

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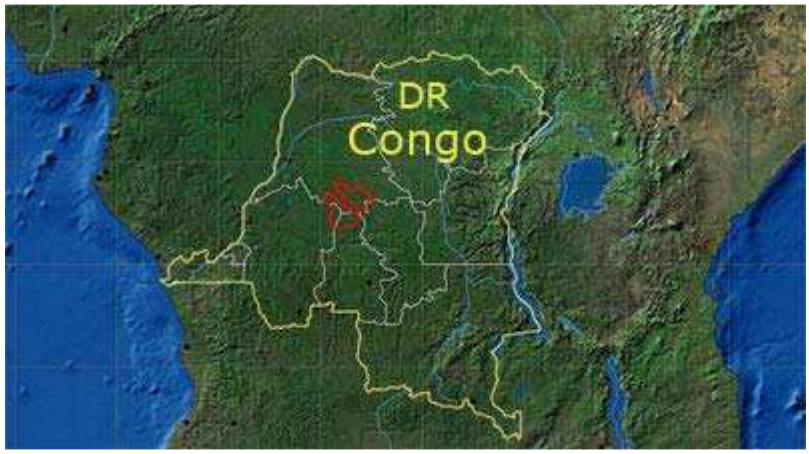
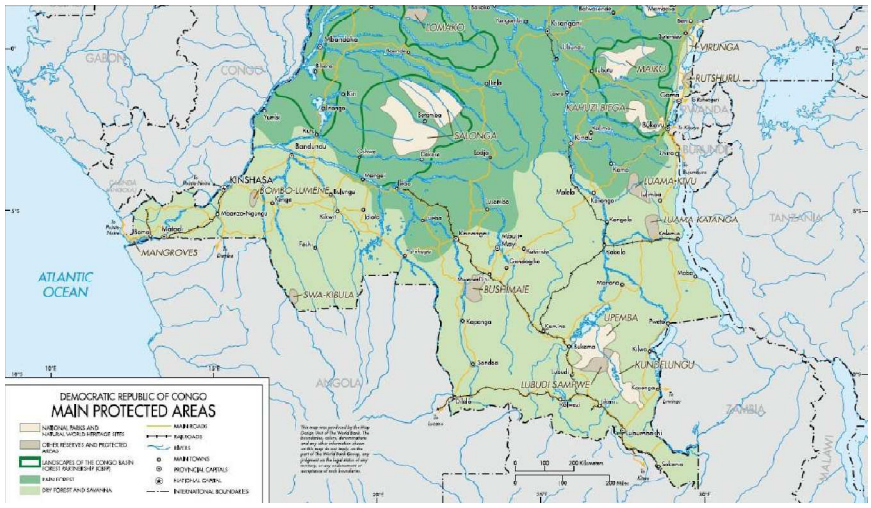
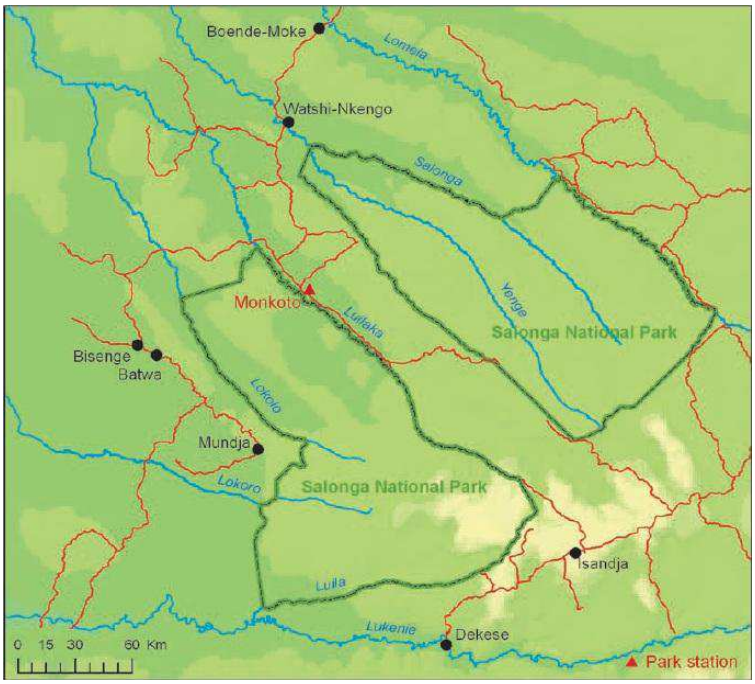
10. Annexes: location of Salongo National Park with its two blocks






Boende-Moke
Lomela
Watshi-Nkengo
Salonga
Monkoto
Lukaka
Yenge
Salonga National Park
Bisenge
Batwa
Lokolo
Mundja
Lokoro
Salonga National Park
Isandja
Lulla
Lukenie
Dekese
0 15 30 60 Km
Park station